

EVALUATION BY ACCELEROMETRY OF WALKING PATTERN BEFORE FALLS IN HEMIPLEGIC PATIENTS

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Abstract—Hemiplegic patients often fall because of a lack of balance during walking. They can become bed-ridden, or suffer falling syndrome after falling. The aim of this study was to evaluate the walking pattern just prior to falls among high-risk patients in a rehabilitation setting. A triaxial accelerometer was fixed to the subject's waist, and the triaxial acceleration signals were recorded. Thirty-one subjects walked down a corridor under supervision. The data were digitized at a sampling rate of 200 Hz, and analysed using a discrete wavelet transform. The variables required to evaluate falls were related to the reconstructed signal at level -3. We classified falls into three types. In Type 1 falls, the impact acceleration signals in the vertical direction were larger in walking just prior to a fall. In Type 2 falls, small impact acceleration signals in the vertical direction were observed. In Type 3 falls, the walking cycle changed irregularly just prior to a fall and the impact acceleration was larger and smaller before the fall. From these results, falls were evaluated. The next step will be predicting falls.

Keywords— Falls, wavelet transform, accelerometry, evaluation

I. INTRODUCTION

Patient falls are the most important problem in geriatric care and rehabilitation. The risk of a fall is especially high among hemiplegic patients, and falling is one of the most frequent complications among hemiplegic patients during rehabilitation. During the past decade, rehabilitation has become increasingly important in patient care. This is a favourable development in many respects, but the risk of falls can also increase, at least in the short-term, with the emphasis being on the patient's mobility and independence. Consequently, reducing the risk of a fall should be an essential factor in rehabilitation strategies; however, very little attention is paid to this issue. The causes of gait disorder and falls have been studied, but the mechanism of falls has not been evaluated. Most clinical studies have focused on systemic and epidemiological factors contributing to the risk of a fall. The aim of this study is to use accelerometry to analyse walking in patients with hemiplegia, and to investigate the mechanism of falls.

II. SUBJECTS AND METHODS

The experiments were performed with 16 hemiplegic patients with ambulatory independence, and with 21 patients who experienced falls. The characteristics of the subjects are summarized in Table 1. The Fujimoto-Hayasuzu Hospital

Ethics Committee approved this experiment, and informed consent was obtained in writing from each patient. The patients walked down a corridor using their own assistive device, such as a cane or ankle foot orthosis, under supervision. When patients lost their balance during walking, a physiotherapist supported them during the fall. The acceleration signals were digitized with a sampling rate of 200 Hz. The walking pattern was also recorded on videotape. After the experiments were completed, the data were transferred to a personal computer for further analysis. To evaluate the falls, the data for loss of balance were analysed by the discrete Daubechies wavelet with order 4. The acceleration signal was decomposed into 12 levels. Although these levels depended on the sampling frequency, a detailed signal at each level and the approximation signal at level 12, which covered all the frequency bands of walking, were used for the analysis. A reconstructed signal at each level was used to evaluate falls. The characteristics of the falls were then confirmed from the video recordings.

III. RESULTS

On the decomposition of the wavelet transform, the peaks corresponding to impact acceleration were observed at level -3 (frequency range of 12.5 to 25 Hz) in the vertical, direction, in patients with ambulatory independence.

Fig. 1 shows a typical example of the wavelet detail at level -3 in the vertical direction. These peaks are periodic, with repeatable amplitude at the non-hemiplegic and hemiplegic sites: a large peak corresponds to contact of the control site with the floor, and a small peak represents contact of the hemiplegic site with the floor. The reconstructed signal in the anteroposterior and lateral directions was not repeatable.

In patients who experienced falls, impact acceleration peaks observed at level -3 in the vertical direction were different from those in the ambulatory independent patients. From the peaks observed at level -3, we classified falls into three types. Fig. 2 shows a typical signal of a Type 1 fall: a relatively large (compared with stable walking) peak before falling is seen in eight of the 31 patients. Fig. 3 shows a typical signal of a Type 2 fall: a small peak before falling was observed in 11 patients. In both cases, the walking cycle changed irregularly before the fall. In the two Type 3 falls, the walking cycle was irregular before the falls, but the impact acceleration was not regular; impact acceleration increased and decreased irregularly before falls.

Analysis of the video recordings showed that, in Type 1

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falls, the subject had difficulty elevating the lower extremity, so the hemiplegic site swung with reaction. As a result, the center of gravity moved forward rapidly and deviated from the base of support, and the fall followed. In addition, the place contacted on the floor was a little further away than in stable walking. In Type 2 falls, either the hemiplegic leg could not swing properly and caught on the floor, or the leg gave way. In Type 3 falls, an irregular walking pattern appeared a few steps before the fall.

IV. DISCUSSION

Our results show that patients with ambulatory independence have periodic impact acceleration, with relatively constant amplitude. The signals for these patients were highly reproducible, and the patients maintained stable walking.

The signals obtained from patients who experienced falls show an irregular peak before a fall. From the video recordings, we observed that patients who had Type 1 falls had a larger impact acceleration before falls, because of a faster swing in the hemiplegic site. In contrast, the impact acceleration was smaller in Type 2 falls, because the hemiplegic leg caught on the floor, which prevented the hemiplegic leg swinging and caused the fall. Patients who had Type 3 falls had unstable walking patterns, indicating that they had not yet relearned the mechanics of walking.

These results indicate that wavelet analysis of the acceleration signal is useful for evaluating falls.

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TABLE 1. List of patients.

	Case group	Control group
Right hemiplegia	12	7
Left hemiplegia	9	9
Male	12	12
Female	9	4
Age in years (SD)	70.5±10.6	61.1±11
Disease (SD)	18.1±17.1	50.4±31.1
Brunnstrom stage		
Lower extremity III	16	8
IV	4	8
V	1	0

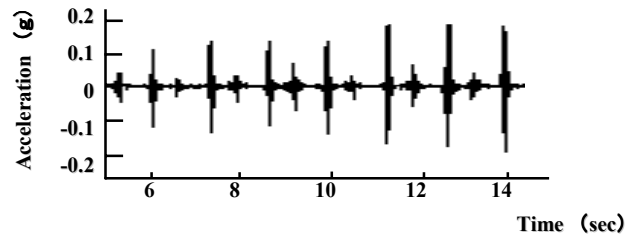


Fig. 1. A typical example of a reconstructed acceleration signal at level -3 in the vertical direction for patients with ambulatory independence.

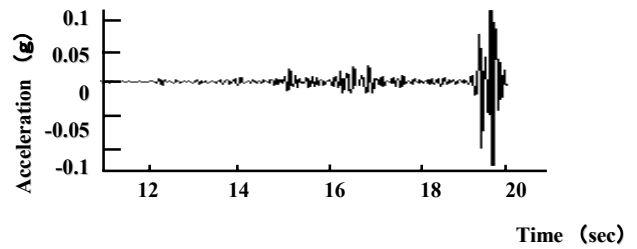


Fig. 2. A typical example of a reconstructed acceleration signal at level -3 in the vertical direction for a Type 1 fall.

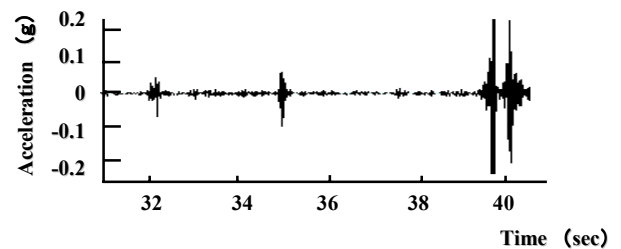


Fig. 3. A typical example of a reconstructed acceleration signal at level -3 in the vertical direction for a Type 2 fall.

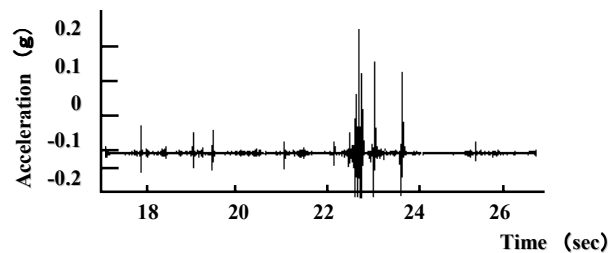


Fig. 4. A typical example of a reconstructed acceleration signal at level -3 in the vertical direction for a Type 3 fall.